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Doppler Echocardiographic Features of Ventricular Septal Rupture in Myocardial Infarction

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Doppler echocardiography was used to evaluate the features of interventricular septal rupture in six patients with acute myocardial infarction and to substantiate the hemodynamic data and morphologic findings at surgery or autopsy. Although echocardiographic visualization of the septal rupture was obtained in only two of the six patients, unusual Doppler flow signals were detected in the apical portion of the right ventricle in all six patients. Five patients had unusual flow signals during both systole and diastole; one had such signals only during systole. The location of these unusual flow signals coincided with the site of septal rupture confirmed at surgery or autopsy. The pattern of the flow signals in one cardiac cycle was very similar to that of the pressure difference between the left and right ventricular cavities. These findings indicate that the unusual flow signals represent the left to right shunt flows resulting from septal rupture.

In conclusion, Doppler echocardiography may be a very useful tool for diagnosing interventricular septal rupture easily and noninvasively in patients with acute myocardial infarction.

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Rupture of the interventricular septum, one of the most serious complications of acute myocardial infarction, requires accurate diagnosis to decide proper management and indications for surgery (1,2). When the initial diagnosis is made on the basis of phonocardiographic findings, it may fail to differentiate septal rupture from mitral regurgitation due to papillary muscle dysfunction (3–5).

It has been reported (6) that pulsed Doppler echocardiography in congenital ventricular septal defect shows unusual Doppler signals from the septum to the right ventricular cavity which may be attributable to left to right shunt, and that the diagnostic sensitivity of this technique is very high for ventricular septal defect. Hence, it is expected that ventricular septal rupture in myocardial infarction is diagnosed by detecting unusual flow in the right ventricular cavity.

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Richards et al. (7) observed unusual flow signals near the right ventricular side of a ruptured septum using the combination of Doppler and M-mode echocardiography. Keren et al. (8) added new information concerning unusual flow in the right ventricle from a ruptured septum using the combination of pulsed Doppler and two-dimensional echocardiography.

In the present study, attention was focused on the relations between Doppler echocardiographic findings, transseptal hemodynamic data and morphologic data at surgery or autopsy to substantiate the efficacy of the Doppler technique for diagnosing septal rupture in myocardial infarction.

Methods

Patients. Six patients with myocardial infarction who had shown sudden onset of a pansystolic murmur in the acute stage of their disease, strongly suggesting ventricular septal rupture, were observed at our institution from 1981 to 1983. They were three men and three women ranging in age from 59 to 75 years. In all six patients, the pansystolic murmur was loud in the area from the left sternal border in the fourth intercostal space to the apex. The murmur had a presystolic component in five of the six patients (Fig. 1).

Hemodynamic, surgical or autopsy confirmation. For determining the definite diagnosis, four of the six patients

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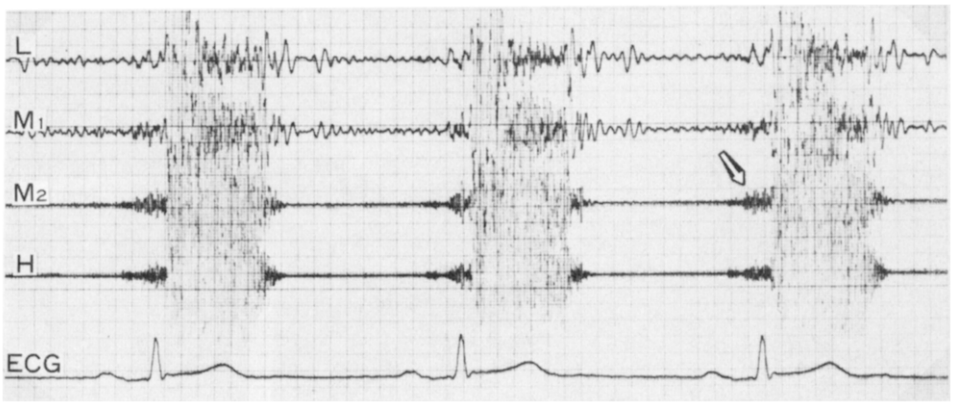


Figure 1. Case 5. Phonocardiogram showing a pansystolic murmur and presystolic murmur (**arrow**) recorded at the apical area. ECG = electrocardiogram; H = high frequency phonocardiogram; L = low frequency phonocardiogram; M_1 = medium low frequency phonocardiogram; M_2 = medium high frequency phonocardiogram.

underwent left and right heart catheterization and left ventriculography; and the remaining two patients had only right heart catheterization. A left to right shunt was noted in all six patients. Three of the four patients who had both procedures underwent cardiac surgery. The two patients who had only right heart catheterization died and underwent autopsy. In five of the patients, the presence of ventricular septal rupture was ultimately confirmed by direct observation.

Control group. Ten healthy subjects and 50 patients with old myocardial infarction and no clinical evidence of ventricular septal rupture were examined as a control group. Their ages ranged from 40 to 67 years.

Doppler echocardiography. Commercially available two-dimensional Doppler systems were used, incorporating a pulsed Doppler flowmeter in an ultrasonic wide angle phased array system, a Toshiba SSH11A/SDS10A and a Toshiba SSH40A/SDS21A, with an ultrasound frequency of 2.4 MHz and pulse repetition rate of 4 or 6 kHz. The sample volume was 4 mm wide and 2 to 3 mm deep. The Doppler signals were analyzed by the fast Fourier transform principle, so that flow direction and velocity were displayed as a sound spectrogram.

Two-dimensional Doppler echocardiographic examinations were performed in all six patients before the definite diagnosis was determined. Five of the six patients were examined in the acute phase of myocardial infarction and one in the chronic phase. The four cardiac chambers, great vessels and valve orifices were searched for unusual Doppler signals, using a variety of approaches for detecting valve regurgitation and shunt flows. The findings of the Doppler examination were compared with those of cardiac catheterization, angiocardiography, surgery and autopsy.

Results

Echocardiographic and Doppler Flow Abnormalities (Table 1)

Interventricular septum and ventricular cavities. Interruption of the ventricular septal echo was visualized by two-dimensional echocardiography in two patients (Cases 5 and 6), one in the chronic phase and the other in the acute phase of myocardial infarction. Their apical four chamber views showed systolic thinning and akinesia in the apical half of the interventricular septum and interruption of the septal echo at the margins of the thinned areas. In these two patients, unusual flow signals were detected at the site of echo interruption. These signals were characterized by a rapid flow away from the apical region during systole, followed by a momentary stop in the flow during early diastole, which could not be clearly identified because of a filter in the equipment that eliminated low frequency Doppler signals due to motion of the intracardiac structures. There was then a flow in the same direction during diastole, which was slower than the systolic flow with a slight acceleration during presystole (Fig. 2). In the right ventricular cavity in the vicinity of the septal echo interruption, bidirectional Doppler signals, indicating a very speedy turbulent flow, were noted during systole, followed by a slow flow away from the apical region during diastole (Fig. 3). An intermediate four chamber view (between the apical and parasternal projections) was advantageous in detecting these abnormalities.

Echocardiograms of the other four patients (Cases 1 to 4) did not clearly visualize the septal echo interruption, although they did reveal akinesia and systolic thinning in the apical half of the interventricular septum. In three of these four patients, an unusual rapid flow in systole and a slower flow in diastole, as seen in the vicinity of the septal echo interruption on the echocardiograms of Patients 5 and 6, were detected in the right ventricular cavity, being localized in a small region close to a marginal part of the thinning area of the septum. In the remaining patient (Case 4), unusual Doppler signals were detected in the same area only during systole.

These unusual flow signals seen in our six patients at the site of the interruption of the septal echo and in the apical half of the right ventricular cavity were not seen in the control group of healthy subjects and patients with old myocardial infarction with no clinical evidence of ventricular septal rupture.

Table 1. Two-Dimensional Doppler Echocardiographic Findings and Clinical Data in Six Patients

Case	Age (yr) & Sex	Site of Myocardial Infarction	Cardiac Catheterization Data: Pressures (mm Hg) RV	Pressures (mm Hg) LV	L-R Shunt Ratio (%)	Oxygen Saturation (%)	Heart Murmur at Apex	Unusual Doppler Flow Signal in RV	Septal Echo Interruption	Rupture Size by Surgery, Autopsy* or Angiography† (mm)
1	62M	Anteroseptal	35/0–0	107/2–15	63	RA: 61.2, RV: 91.8, PA: 85.7, Ao: 91.8	Pansyst., presyst.	Syst. + diast.	—	13
2	61F	Anteroseptal	23/−3–0	86/4–9	45	RA: 66.6, RV: 85.3, PA: 81.9, Ao: 94.3	Pansyst., presyst.	Syst.	—	15
3	75M	Anteroseptal	35/3–10		36	RA: 63.7, RV: 80.1, PA: 74.3, Ao: 94.5	Pansyst., presyst.	Syst. + diast.	—	10*
4	66F	Anteroseptal	42/0–2	112/0–10	35	RA: 65.1, RV: 74.7, PA: 75.2, Ao: 93.1	Pansyst.	Syst. + diast.	—	9†
5	59M	Anteroseptal	32/−1–2	86/0–13	62	RA: 70.5, RV: 94.1, PA: 87.1, Ao: 96.8	Pansyst., presyst.	Syst. + diast.	+	13
6	71F	Anteroseptal and lateral	43/4–9		72	RA: 64.5, RV: 89.2, PA: 90.5, Ao: 96.3	Pansyst., presyst.	Syst. + diast.	+	15*

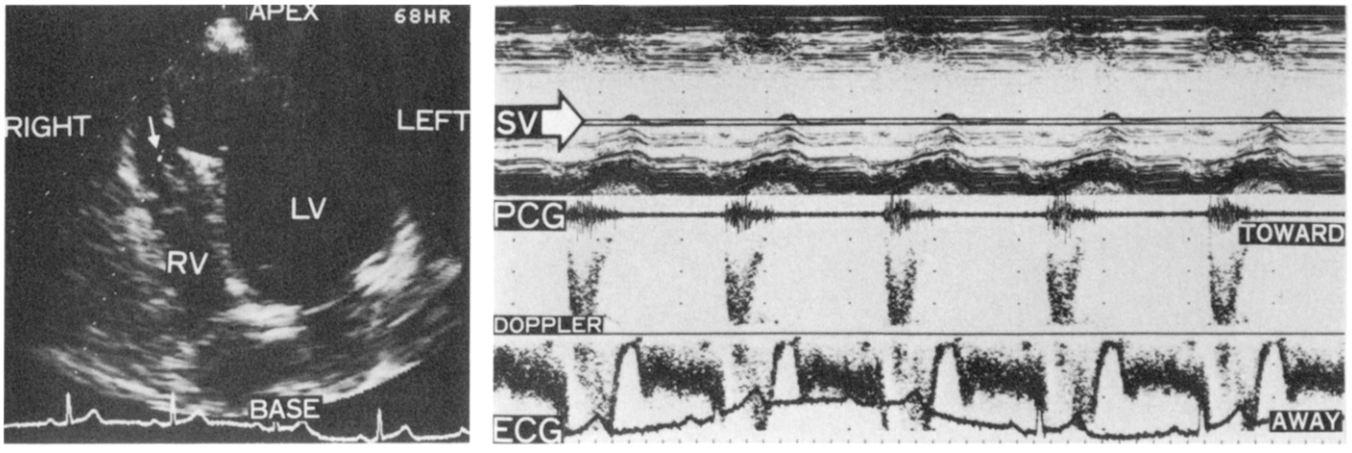
Ao = aorta; diast. = diastolic; F = female; L-R = left to right; LV = left ventricle; M = male; PA = pulmonary artery; Pansyst. = pansystolic murmur; presyst. = presystolic murmur; Pressures = peak systolic/early diastolic-end diastolic; RA = right atrium; RV = right ventricle; Syst. = systolic; + = visualized; — = not visualized.

The contrast echographic study was routinely performed once or twice with peripheral injection of 10 ml of saline solution in all six patients. In three of the six patients, contrast echoes did not reach the apical area of the right ventricular cavity. In the remaining three patients, although the right ventricular cavity was filled by contrast echoes, the study failed to detect a negative jet into the right ventricle and the appearance of contrast echoes in the left ventricle.

Left atrial cavity. In three of the six patients, unusual Doppler signals were noted in the vicinity of the mitral orifice in the left atrial cavity during systole and were interpreted to indicate mild mitral regurgitation (9,10). It was easy to differentiate these signals from the unusual signals in the right ventricular cavity on the basis of the different sites where they were recorded.

Flow through the pulmonary orifice. In all six patients, blood flow through the pulmonary orifice appeared to be slightly faster than usual. However, flow volume measurement was not performed, because the echo of the pul-

Figure 2. Case 5. Doppler recording at the site of interventricular septal rupture in myocardial infarction. **Left panel**, Interruption of the ventricular septal echo (**arrow**) was clearly visualized on the four chamber view from the fifth intercostal space. **Right panel**, Unusual flow signals were recorded at the site of interruption of the ventricular septal echo. A rapid flow away from the apex was observed during systole and a slow flow in the same direction as the systolic flow during diastole with a slight acceleration in presystole. However, the flow velocity markedly decreased in the isometric relaxation phase. Systolic flow velocity was so great that the greatest part of the systolic flow away from the transducer was displayed in the opposite direction as wrapped around the baseline because of the aliasing. ECG = electrocardiogram; LV = left ventricle; PCG = phonocardiogram; RV = right ventricle; SV = sample volume.



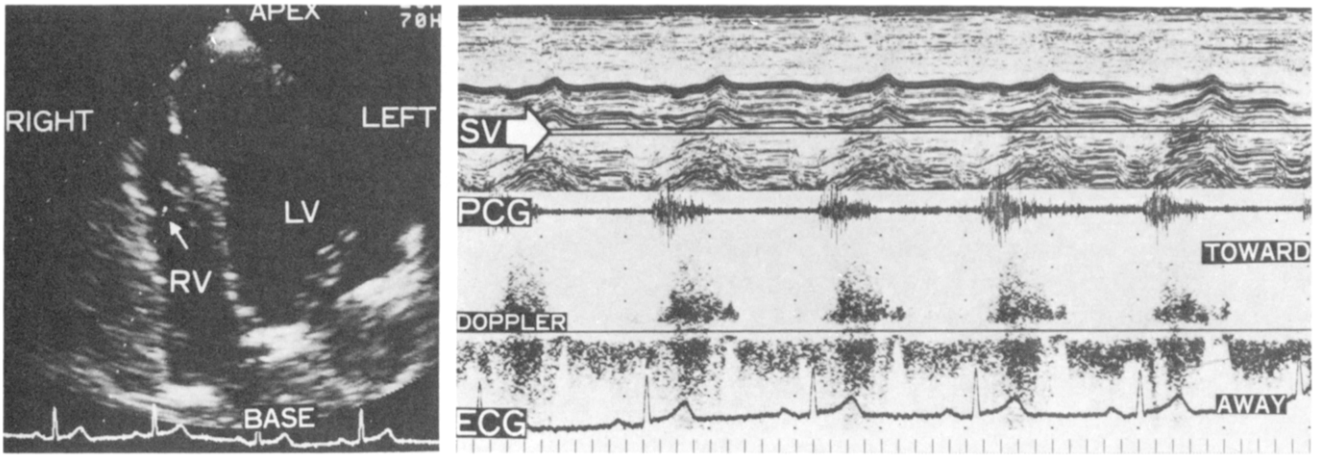


Figure 3. Case 5. Doppler recording in the right ventricular cavity. **Left panel**, Two-dimensional echocardiogram showing the Doppler sampling site, which was located in the right ventricular (RV) cavity near the site of rupture (**arrow**). **Right panel**, Systolic bidirectional turbulent flow signals and diastolic slow flow signals away from the apical region were recorded at the sampling site. Abbreviations as in Figure 3.

monary artery was not adequate enough to measure its inner diameter.

Hemodynamic and Angiographic Data (Table 1)

Shunt flow. In all six patients, step-up of oxygen saturation was noted at the right ventricle, indicating the presence of a left to right shunt at this level. The calculated shunt ratio ranged from 35 to 72% (Table 1).

Figure 4. Case 5. Left ventriculogram and pressure recording. **Left panel**, The site of ventricular septal rupture (**arrow**) was visualized by left ventriculography (left anterior oblique view). **Right panel**, Simultaneous pressure recording showed that ventricular pressure was higher in the left ventricle (LV) than in the right ventricle (RV) throughout the cardiac cycle except during the isometric relaxation phase.

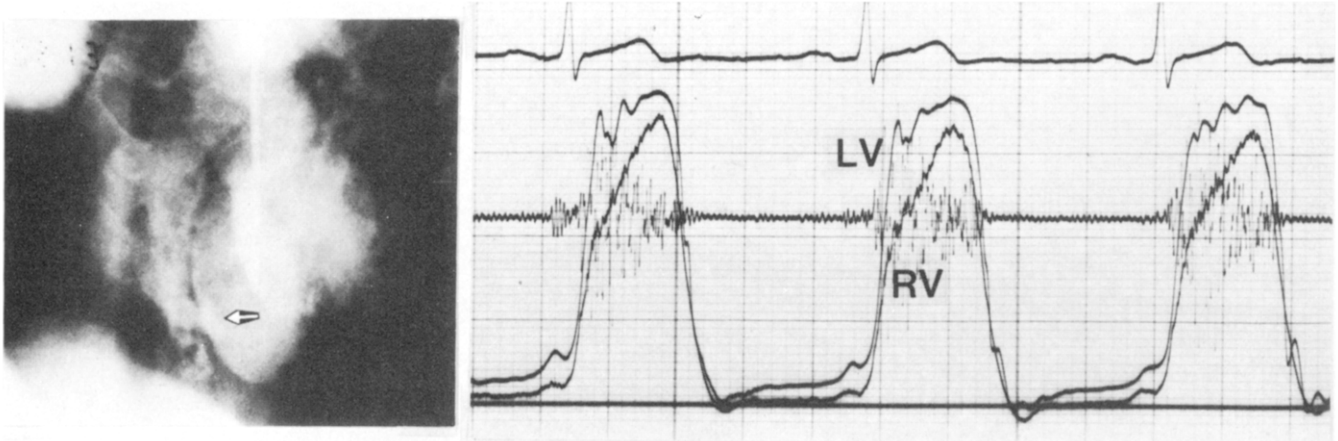
Pressure measurements. In the four patients who underwent the left and right heart catheterization (Cases 1, 2, 4 and 5), pressure measurements demonstrated that left ventricular pressure exceeded right ventricular pressure throughout systole and diastole (Fig. 4). The abnormal Doppler flow pattern seen at the site of septal echo interruption appeared very similar to the pattern of pressure difference between the ventricles.

Left ventriculography was also performed in these four patients. It demonstrated that the apical half of the heart showed akinesia, and that contrast medium appeared in the right ventricle, passing through the interventricular septum (Fig. 4).

Septal Rupture Observed at Surgery or Autopsy

In three patients who underwent surgery (Cases 1, 2 and 5), a septal tissue defect of 13 to 15 mm in diameter was noted in the marginal part of the scar on the interventricular septum near the apex of the right ventricle.

In the two patients who underwent autopsy, a septal tissue defect was noted in the thinned infarcted area of the interventricular septum near the apex. It was 10 mm in diameter in one patient (Case 3), and 15 mm in the other (Case 6).



JACC Vol. 5, No. 1
January 1985:182–7

Discussion

Interpretation of the unusual Doppler signals obtained in the right ventricular cavity. These unusual Doppler signals (6) were recorded in all six patients. Such Doppler signals have never been observed in healthy subjects or patients with other types of disease, including our control subjects and patients who had myocardial infarction without septal rupture. Satisfactory correspondence was observed between the site of the unusual flow signals and the site of rupture observed at surgery or autopsy. Direct observations at surgery or autopsy confirmed that the tissue defects in the interventricular septum were caused by infarction and were not congenital. Therefore, it is assumed that the unusual flow signals are attributable to the left to right shunt caused by ventricular septal rupture.

The pattern of unusual flow through one cardiac cycle was very similar to that of the pressure difference between the left and right ventricles, which supports the assumption that the findings represent shunt flow. The presystolic acceleration of the flow can be attributed to the maximal difference of the diastolic pressure in presystole being compatible with the presence of a presystolic accentuation of the heart murmur in our patients (11,12). Thus, it is concluded that the unusual flow signals in the right ventricular cavity observed in our study resulted from a left to right shunt through the rupture site of the interventricular septum.

Significance of Doppler echocardiography as a diagnostic tool for ventricular septal rupture in myocardial infarction. Two-dimensional echocardiography has enabled the visualization of septal rupture in some but not all patients with myocardial infarction (13). In our study, rupture was visualized in only two of six patients. A contrast technique has been considered to be useful for the diagnosis of rupture (14). However, even with this technique, it has been rather difficult to find a positive contrast echo in the left ventricle and thin negative jet in the right ventricular cavity filled with contrast echoes within a few beats after injection of the contrast material. This was also the case in the present study. With the use of the Doppler technique which permitted the search for unusual signals without limiting time, the presence of septal rupture was determined in all of our six patients. Thus, even if no interruption of the septal echo is visualized by two-dimensional echocardiography, the presence of unusual flow signals in the right ventricular cavity may indicate ventricular septal rupture in patients who exhibit other suspected signs of septal rupture. In clinical practice, it is possible to estimate rupture site noninvasively by searching the septum and right ventricular cavity for a spot where the shunt flow signals are most clearly and powerfully detected. In our experience, the detection of the unusual Doppler signals in the right ventricular cavity generally appeared to be easy. The reason for this ease of diagnosis may be that the rupture site in myocardial infarction is generally near the cardiac apex so that it is easy to approach echocardiographically from the apical region. In the present study, the defect size was rather large with a high shunt ratio. This might be another reason for the ease of diagnosis.

Mitral regurgitation. Mitral regurgitation due to papillary muscle dysfunction is another major source of the acute appearance of a systolic murmur in myocardial infarction. In general, the Doppler technique has been considered to be helpful in differentiating mitral regurgitation and ventricular septal defect (15). The unusual Doppler signals due to mitral regurgitant flow are detected in the left atrial cavity (16), as was also the case in the present study, so that the site of mitral regurgitant signals is far from that of the interventricular shunt caused by septal rupture. Thus, the Doppler technique may be advantageous also in differentiating whether the acute onset of a systolic murmur results from ventricular septal rupture or from papillary muscle dysfunction.

Congenital ventricular septal defect. There may be patients with congenital ventricular septal defect who suffer also from myocardial infarction. The acute onset of a systolic murmur may be helpful to differentiate this type of defect and septal rupture. If the time of onset of the systolic murmur is unknown, it is doubtful whether the Doppler technique alone can differentiate these two conditions, although unusual Doppler flow signals due to congenital ventricular septal defects are observed typically in the right ventricular outflow tract rather than at the apex. However, the incidence of this problem may be very low.

In summary, the Doppler technique linked with two-dimensional echocardiography is a very useful method for diagnosing ventricular septal rupture early without any stress on the patient, even in the emergency of acute myocardial infarction. With this technique, it is possible to diagnose rupture and estimate the rupture site.

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